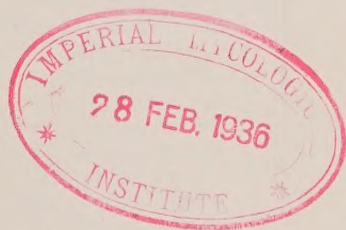

New York State Agricultural Experiment Station
Geneva, N. Y.

MOSAIC OF THE REFUGEE BEAN

ARTHUR L. HARRISON



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ABSTRACT

BEAN mosaic has been unusually severe in New York on the variety Stringless Green Pod Refugee since 1928. Previous to 1928 the records indicate that the disease was not of unusual severity, except for a period of a few years preceding 1920 when it took heavy toll from the bean crop.

The symptoms of bean mosaic on the variety Stringless Green Pod Refugee are described in some detail. They vary depending on the stage of growth at time of infection, the season of the year, and individual differences in the plants themselves.

The viruses causing mosaics of red clover, alsike clover, black medick, and white sweet clover are all transmissible to the bean by means of the pea aphid, but they produce a disease that is distinct from bean mosaic. This disease is known as yellow bean mosaic. In one case, however, bean mosaic was obtained from a mosaic-infected white sweet clover plant.

Bean mosaic is a seed-borne disease. In the field the chief mode of spread is by means of various sucking insects. Winds and cultivators also may aid slightly in disseminating the disease. Bean mosaic does not spread as rapidly in exposed portions of fields as it does in the sheltered portions.

Bean mosaic causes (1) a reduction in the yield by 10 to 20 per cent, (2) the production of poor quality pods, (3) the formation of curved and crooked pods, (4) the occurrence of hydrotic pods which cause dark beans in the can, and (5) a delay of several days in the time of blooming which may make it necessary to pick an extra time.

The control of bean mosaic by planting mosaic-free seed and by field roguing has been successful only where mosaic did not spread very rapidly. Marked progress, however, has been made in the development of mosaic-immune stocks by making reciprocal crosses between the susceptible Stringless Green Pod Refugee and the immune Robust, and then by making reciprocal back crosses between the most desirable mosaic-immune hybrids and the Stringless Green Pod Refugee. Besides being immune, some of these back-cross hybrids possess many of the desirable characteristics of the Refugee bean and so should make good canning varieties.

MOSAIC OF THE REFUGEE BEAN¹

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INTRODUCTION

The problem of bean mosaic has confronted the canners and growers of snap beans for many years, but not until recently has the serious nature of the malady been fully understood. Many canners and snap bean growers still are unaware of its presence, primarily because of the insidious nature of the disease.

According to reports in the *Plant Disease Reporter*, the losses sustained by snap bean growers in New York State for the years 1930 to 1933 have ranged from 8 to 15 per cent of the total crop. Previous to 1930 the records for field beans and snap beans usually are combined so that an estimate of the losses caused by bean mosaic on the snap bean varieties is not possible. Nevertheless, the trend indicates that the disease was not as serious from 1920 to 1928 as it was before 1920 or since 1928. The loss in New York State in 1929 was 10 per cent of the total bean crop, including both field and snap beans. This loss, however, probably was sustained mostly by the Stringless Green Pod Refugee variety. The reason for this fluctuation in the severity of the disease is not clear but probably is related to the prevalence of the insects which carry the virus causing the disease from plant to plant.

All of the commercial varieties of snap beans are susceptible to mosaic, altho some are more or less resistant to the disease. In general, mosaic is not a serious problem on the wax varieties, but it is a very serious problem on the popular canning variety, Stringless Green Pod Refugee. On this variety it consistently reduces the yield by 10 to 20 per cent, causes misshapen and crooked pods, causes dark pods in the can, and lessens the time which the beans can be held before canning. In other words, bean mosaic is involved in many of the problems which confront the growers and canners of beans.

Since bean mosaic is such a serious disease on the variety Stringless Green Pod Refugee, investigations were conducted to see whether or not its ravages could be eliminated or greatly reduced on this variety.

¹The investigations on bean mosaic were sponsored by the Rogers Bros. Seed Co., Chicago, Ill. The technical aspects of the investigations are presented in Technical Bulletins Nos. 235 and 236 of this Station.

DESCRIPTION OF THE DISEASE

The symptoms of the common bean mosaic on the variety Stringless Green Pod Refugee vary according to climatic conditions, type of leaf, time of infection, and individual differences in the plants.

Leaf symptoms of bean mosaic may be classified into two groups, *first*, early symptoms or those symptoms produced on leaves expanding at the time of inoculation; and *second*, typical symptoms or those produced on seed-infected plants and those produced subsequent to the early symptoms.

The leaves that show the early symptoms of bean mosaic are crinkled, chlorotic, and stiff. The leaves droop and the petioles are much shortened (Fig. 1). No definite downward rolling of the mar-



FIG. 1.—EARLY SYMPTOMS OF BEAN MOSAIC.

Note the short stems of compound leaf on the plants in the pot on the left and on two of the plants in the pot on the right. The three plants with long stems on the first compound leaves are healthy.

gins of the leaflets occurs nor is the characteristic mosaic mottling present. Mosaic-infected plants occasionally fail to develop these early symptoms.

On simple leaves showing typical symptoms there may be a general chlorosis of the leaf blade or a definite pattern of light green and dark



FIG. 2.—SYMPTOMS OF BEAN MOSAIC IN THE SIMPLE LEAVES.

Note the downward rolling of leaf margins on the leaf at the left. The leaf on the right is from a healthy plant.

green areas. The light green areas are usually along the margin of the leaf. Frequently a slight downward cupping results, as is illustrated in Fig. 2. Mosaic symptoms occasionally cannot be detected on the simple leaves, especially if climatic conditions are unfavorable for the expression of symptoms.

On the compound leaves, the typical symptoms of mosaic vary considerably. A distinct downward rolling of the leaf margin usually occurs on the leaflets of the first few compound leaves formed on seed-infected plants and on the first few leaves produced after the

leaves with early symptoms (Fig. 3). Associated with this cupping is a distinct mosaic mottling composed of light green and dark green areas. As in the case of the simple leaves, the light areas are more frequent along the margins of the leaflets (Fig. 4). The downward rolling of the leaflets becomes less pronounced as the new growth appears, until finally no rolling of the leaflets is evident. At the same time the light green and dark green areas become progressively smaller until they are very fine and frequently difficult to distinguish. Thus, by midsummer or late summer, the symptoms of mosaic are difficult to distinguish on seed-infected plants and on plants infected early in the seedling stages.

All plants, however, do not react the same to infection with the mosaic virus. On some plants all the leaves produced after infection are distinctly rolled and distorted, as is illustrated in Fig. 5. This condition is more frequent when the days are long and the weather hot and dry.

The reason for the extreme variation in the leaf symptoms exhibited by different individuals infected with bean mosaic is not understood.

Besides these different leaf symptoms, bean mosaic is characterized by a shortening of the internodes, a proliferation of the vines, which is illustrated in Fig. 6, a general stunting of the plant, and a deformation of the pods and flowers.

CROPS AFFECTED

Bean mosaic in New York State is confined almost exclusively to the various species and varieties of beans. However, all species and varieties of beans are not susceptible to mosaic, but all commercial varieties of snap beans acceptable to the trade are susceptible. The popular canning bean, the Stringless Green Pod Refugee, is one of the most susceptible of the canning bean varieties.



FIG. 3.—THE SEVERE LEAF ROLLING SYMPTOMS OF BEAN MOSAIC.

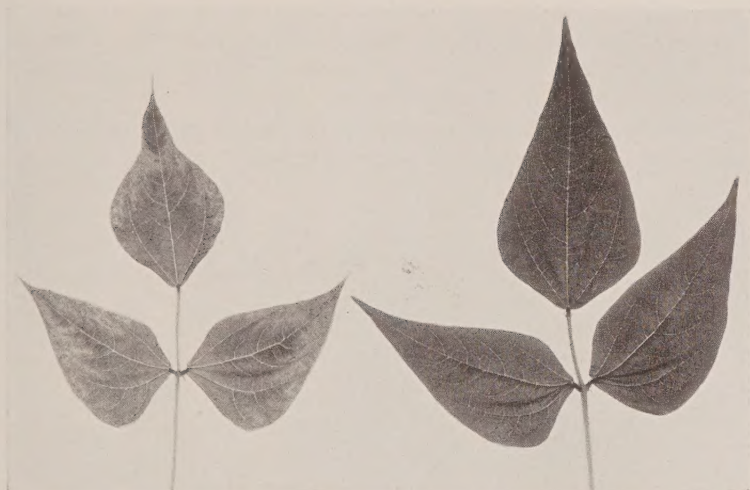


FIG. 4.—MOSAIC MOTTLING CAUSED BY BEAN MOSAIC DURING THE EARLY PART OF THE SEASON.

The leaf on the right is from a healthy plant.

Other legumes in New York State frequently are affected with mosaic diseases, but they differ from bean mosaic. The viruses causing mosaics on red clover, alsike clover, black medick, and white sweet clover all are transmissible by means of the pea aphid to the Stringless Green Pod Refugee, but they produce a disease distinct from bean mosaic. This disease is known as yellow bean mosaic. Fortunately, this disease is not very prevalent in New York State.

In all the experiments with different legume mosaics, bean mosaic was obtained from only one plant other than the bean itself. In that case it was obtained from a diseased white sweet clover plant. This indicates that white sweet clover may harbor the common bean mosaic as well as yellow bean mosaic.

TRANSMISSION OF BEAN MOSAIC

SEED TRANSMISSION

Bean mosaic is a seed-borne disease which unfortunately cannot be detected in the seed by any means available at the present time. The only sure way to tell whether or not a seed is infected is to plant the

seed and examine the seedling for symptoms of mosaic. The percentage of diseased seeds in a sample varies considerably, depending on the prevalence of mosaic in the previous crop, the time the plants became infected, and other factors.

Mosaic is transmitted to a greater percentage of the seeds when the plants are infected in the seed or seedling stages than when they are



FIG. 5.—A HALF-GROWN BEAN PLANT INFECTED WITH MOSAIC IN THE SEEDLING STAGES.

The lower leaves are normal because they were formed before the plant was infected. The upper leaves are curled, twisted and greatly distorted.

infected just before the blooming period. The disease is not transmitted thru the seeds from plants infected after the blooming period. Seeds from the first-formed pods on seed-infected plants carry a higher percentage of mosaic than seeds from the last-formed pods.

Samples of seeds commonly contain from 35 to 40 per cent of diseased seeds and occasionally as high as 60 per cent of the seeds have been observed to be diseased. In general, the incidence of mosaic in a sample of commercial seed varies from 3 to 30 per cent. No lot of commercial bean seed has been found to be entirely free from mosaic.

INSECT TRANSMISSION

In the field bean mosaic is spread from plant to plant chiefly by various species of sucking insects. These insects feed on a diseased plant and then migrate to another plant which, if healthy, will become infected. The point to be emphasized is that the insect must have fed previously on a diseased plant before it can inoculate a healthy plant. Then, and then only, are the sucking insects capable of transmitting the virus which causes the disease.

The following insects have been demonstrated to be transmitters of bean mosaic: Pea aphid, potato aphid, bean aphid, peach aphid, cucumber aphid, cabbage aphid, chenopodium aphid, *Macrosiphum*

ambrosia, and an unidentified species of mealy bug. Altho many kinds of aphids will carry the disease from plant to plant, they are not very common in bean fields. Usually they can be found only with great difficulty.

Many other species of insects which are found on beans do not act as carriers of this disease. These include leafhopper, flea beetle, tar-



FIG. 6.—A FULL-GROWN BEAN PLANT WITH EXCESSIVE BRANCHING OF THE VINES CAUSED BY MOSAIC.

nished plant bug, bean leaf beetle, 12-spotted cucumber beetle, striped cucumber beetle, red spider, thrips, and white fly.

MECHANICAL TRANSMISSION

Wind and cultivators may cause transmission of bean mosaic when they rub together the leaves on diseased and healthy plants sufficiently to cause injury to the leaves. In this process some of the virus which causes the disease is transferred from the mosaic-infected plant to the healthy plant.

The spread of bean mosaic by wind and cultivators, however, will never be of any practical importance in fields in which the percentage

of diseased plants is low because of the time factor and because high winds occur only occasionally during the growing season, but it may be of importance in fields in which the percentage of mosaic is high at the beginning of the season.

FACTORS AFFECTING FIELD SPREAD

During the seasons of 1932, 1933, and 1934, the observation was made and verified that bean mosaic does not spread as rapidly on exposed knolls, slopes, and plateaus as it does in sheltered areas. This would appear, on the surface, to be contradictory to the statements made in the preceding sections, but it emphasizes the point that transmission of bean mosaic by such agencies as wind and cultivators is of minor importance and that transmission by insects is of major importance.

The location of the bean field in relation to other legumes was also observed to influence the spread of bean mosaic. Fields near to or adjacent to fields of clover and alfalfa, especially those on the eastern or southern sides, suffered more from mosaic than bean fields at some distance from fields of clover and alfalfa. Other factors, such as exposure, may counteract this to such a degree that a negative relationship appears to exist.

Fields of clover and alfalfa may influence the rate of field spread of bean mosaic in two ways, *first*, as food plants for the aphids, and *second*, as a source of primary inoculum. The former is probably of more importance than the latter in New York State, since the mosaics which commonly occur on clover and alfalfa in the vicinity of Geneva are different from bean mosaic. Further investigations may show, however, that bean mosaic is widespread in some of the other legumes.

Clover and alfalfa fields are probably very important as breeding grounds for aphids. From such breeding grounds, the aphids migrate to other fields, many of them finding bean fields where they act as transmitters of bean mosaic. Winds and the cutting or dying of the legumes probably aid materially in the migration of the insects.

EFFECT OF MOSAIC ON YIELD

Bean mosaic is of extreme economic importance, partly because it consistently reduces the yield and partly because it is responsible for the production of poor-quality pods. The reduction in yield, however, frequently goes unnoticed because of the insidious nature of the disease and because the grower is unaware of its presence.

The annual reduction in yield from bean mosaic ranges from nothing to 25 or 30 per cent. Occasionally even greater reductions have been noted. Some data² on the effect of mosaic on yield were obtained in 1931 by Dr. James G. Horsfall of this Station. The experimental plats consisted of six rows 72.5 feet long, each plat having an area of 1/50 acre. The mosaic-infected plants were removed from three of the rows in each plat and the healthy plants from the other three rows by roguing on July 22 and again on August 4. The average number of plants per row was thus reduced from about 200 to 70 in both the mosaic-infected and healthy rows. The first picking was made on August 18. A summary of the results, presented in Table 1,

TABLE 1.—EFFECT OF MOSAIC ON YIELD OF BEANS.*

DATE OF PICKING	SERIES NO.	TOTAL YIELD IN POUNDS FROM THREE REPLICATIONS		YIELD IN POUNDS PER ACRE	
		Healthy	Mosaic	Healthy	Mosaic
Aug. 18.....	1	0.82	0.17	27	6
	2	1.42	0.20	47	7
Aug. 22.....	1	11.40	3.96	380	132
	2	14.10	3.93	470	131
Aug. 27.....	1	44.90	20.55	1,497	685
	2	39.99	19.61	1,333	653
Total.....		112.63	48.42	3,754	1,614

* The writer is indebted to Dr. James G. Horsfall for these data.

shows that the reduction in yield is more pronounced in the first picking than in later pickings; nevertheless, the healthy plants yielded approximately twice as many pounds of beans as did the mosaic-infected plants. Altho the yield is low in tons per acre, the fact must be kept in mind that approximately two-thirds of the plants were removed rather late in the season.

Additional data on yield reduction by mosaic were obtained from a 5-acre commercial field in Cato, N. Y., in 1934. Three acres of the field were planted with mosaic-free seed and 2 acres with commercial seed. At harvest time the incidence of mosaic ranged from 3 to 7 per cent in the former and from 15 to 30 per cent in the latter portion of the field. The yield records, obtained thru the courtesy of

² The records were obtained from a fertilizer experiment located on the canning crops farm of this Station.

the Red Creek Canning Company, showed that the portion of the field planted with commercial seed yielded only 3.48 tons per acre as compared to 4.15 tons per acre for the portion planted with mosaic-free seed, or a decrease in yield of 16.1 per cent. Most of the difference in yield was due to mosaic, altho part of it may have been due to soil conditions.

This reduction in yield on diseased plants is due mainly to the stunting effect of the disease, since experiments have shown that mosaic-infected and healthy plants of the same size produce approximately the same number of pods. Consequently, if the beans are grown in good, fertile, well-drained soil with plenty of moisture and in favorable weather, the reduction in yield will not be as noticeable as if the beans are grown under adverse conditions. Nevertheless, the yield from mosaic-infected plants grown under ideal conditions will be less than that from healthy plants grown under the same conditions. The data presented in Technical Bulletin No. 235 of this Station illustrate this point. The reduction in yield was much more pronounced in the experiments in which the plants were crowded and grown under adverse conditions than in the experiments in which conditions were more or less favorable for the growth of beans.

Nevertheless, it is possible to have a bean field in which all of the plants are infected with mosaic outyield a bean field which has little or no mosaic simply by having the former under ideal growing conditions and the latter under adverse soil and moisture conditions. The case, however, of a mosaic-infected field outyielding a healthy field is rare, while the reverse is the rule.

EFFECT OF MOSAIC ON QUALITY

Mosaic greatly reduces the quality of the bean crop as well as the yield. The pods produced on mosaic-infected plants are more curved and crooked than those produced on healthy plants, and frequently are hydrotic with hard, roughened, edematous surfaces.

The curved and crooked pods are a curse to the canner because of the trouble they cause in the mechanics of snipping, grading, and cutting the beans. Altho mosaic is partly instrumental in causing crooked beans, other factors also influence their production, such as vigor of plants and number of pickings. The pods are straighter on vigorous plants than on weak, sickly plants and the number of curved pods increases with each picking. Thus, mosaic, by interfering with the normal development of the plant, increases the number of misshapen pods.

Hydrosis of the pods is another condition which is influenced by mosaic. It is always associated with mosaic-infected plants, but all infected plants do not produce evident symptoms of hydrosis. It is produced only under certain environmental conditions on plants infected in the seed or seedling stages, but is almost invariably present on the pods of plants infected just before or during the blooming and podding stages.

The pods on recently infected plants, aside from being severely hydrotic or water-soaked, are usually hard, rough, and edematous. Such pods are of very little value, as they are of poor quality when canned. They are illustrated in Fig. 7.

Another point which needs to be considered is that mosaic-infected pods lose water faster than healthy pods. Consequently, packing the beans as soon as possible after picking is necessary to preserve the flavor and quality.

During the last few seasons various canners have been troubled with a rusty condition on the surface of the pods, especially noticeable on pods which have been held too long on the warehouse floor or in the field. This rusty condition is more serious on pods from mosaic-infected plants than on pods from healthy plants. The surface of many of the mosaic-infected pods is rough and pimply and, therefore, easily injured during the picking and trucking operations which rub off the tops of the pimples exposing the tender tissues below. These areas quickly turn brown and give the pods a rusty appearance. The fact that mosaic-infected pods lose water faster than healthy pods may also be a factor in the production of the rusty condition.

If the beans have to be held for a time before canning, it is necessary to spread them out so that they will not heat, since the oxidation processes which bring about the changes in color proceed faster at a high temperature than at a low temperature.

To determine the effect of mosaic on the quality of the bean in the can, two canning tests were conducted—one in 1933 thru the courtesy of the Halstead Canning Company at Cortland, N. Y., and one in 1935 thru the courtesy of the Geneva Preserving Company at Geneva, N. Y. Some of the cans in these tests were opened a few days after canning in the presence of various authorities who are familiar with canned beans. All agreed that the mosaic-infected pods were darker in color. The darkened condition of the mosaic-infected pods, resulting primarily from their hydrotic condition, was very evident before as well as after the canning process. The contrast in color was more



FIG. 7.—HYDROSIS OF PODS CAUSED BY BEAN MOSAIC.

The two pods on the right are from plants infected during the blooming period. Note the dark pimply condition of the pods. The two pods on the left are from healthy plants.

pronounced in the tests conducted in 1933 than in the test conducted in 1935. This difference is probably due to the fact that in 1933 the diseased pods were picked from plants infected during the blooming and podding stages and consequently were very hydrotic, whereas in 1935 the diseased pods were picked from plants infected in the seed or seedling stages and so did not have a severe case of hydrosis.

No distinct differences could be detected in the flavor of the mosaic-infected and healthy beans, but the latter appeared to be more tender than the former. The healthy beans, also, had a finer, cleaner, more attractive appearance than did the mosaic-infected beans.

The differences between the mosaic-infected and healthy pods are not so pronounced after the beans have stood in the cans for a few months or even a few weeks, because of the action of the tin on the beans.

EFFECT OF MOSAIC ON MATURITY

Mosaic-infected plants do not bloom or mature their pods as soon as do healthy plants. On seed-infected plants and on plants infected in the seedling stages, the delay in blooming and consequently in the maturity of the pods is approximately 10 days. However, if infection does not take place until just prior to the blooming period, the delay in blooming is even longer. When plants are infected during the blooming period there is a cessation of blooming for several days which is followed by another blooming period.

This delay in the time of maturity has a distinct economic aspect, because in some fields it may be necessary to pick the crop more times to get the same or even smaller yield. This point was well illustrated in the 5-acre field at Cato in 1934. The part of the field, 3 acres, that was comparatively free of mosaic was picked only four times for a yield of 4.15 tons per acre; whereas the remainder of the field, which had approximately 35 per cent mosaic, was picked five times for a yield of only 3.48 tons per acre. Thus, it was necessary, primarily because of mosaic, to pick the vines an extra time and yet obtain only 83.9 per cent as many beans.

CONTROL OF BEAN MOSAIC

Several possible methods for controlling bean mosaic were considered when the work was started in 1932. These methods included the use of mosaic-free seed, the elimination of the virus from the seed, roguing of the mosaic-infected plants as soon as they appeared, the selection of mosaic-resistant or immune stocks from commercial lots of bean seed, and finally, the breeding of a mosaic immune Refugee. The breeding program was known to be a long-time project, but it was started because of the possible failure of all other attempts to control bean mosaic. As the work progressed other possibilities for the control of bean mosaic presented themselves and were considered.

USE OF MOSAIC-FREE SEED

The use of mosaic-free seed seemed to be the logical method for controlling bean mosaic, but unfortunately every sample of commercial seed which was tested carried mosaic. It was necessary, therefore, either to find a method by which the virus could be eliminated from seed samples or to discover a way to produce mosaic-free seed. In the attempts to eliminate the virus from the seed or to eliminate the infected seeds from the samples, heat under dry and moist conditions, X-rays, formaldehyde fumes, and flotation methods were used, but with negative results. All samples of seeds that germinated still carried the mosaic virus. For the details of these experiments, see Technical Bulletin No. 235 of this Station.

Since these attempts to eliminate the virus from samples of seed failed, the production of mosaic-free seed was attempted. This proved successful. In the experiments conducted in 1933 and 1934 mosaic-free seed was obtained by fall roguing. The identification of healthy and mosaic-infected plants is greatly facilitated in the fall because of the delaying effect of mosaic on the time of maturity. The mosaic-infected plants remain green from one to two weeks longer than the healthy plants. Thus, by removing all the late-maturing plants from the field or by harvesting only the early-maturing plants, mosaic-free seed may be obtained. This practice, of course, is possible only in fields in which some of the plants remain healthy until the blooming or podding stages. Early-maturing plants from fields in which all the plants are infected in the seed or seedling stages carry practically the same percentage of mosaic as the late-maturing plants from the same field.

The mosaic-free seed obtained by fall roguing was planted in various localities in New York State in 1934 and 1935 to see whether or not the use of mosaic-free seed would solve the problem of bean mosaic. Unfortunately, bean mosaic spread to a greater or less extent depending on other factors. In some of the plats 100 per cent of the plants were infected early in the seedling stages, while in others only a small percentage of the plants became infected. It is evident, therefore, that the planting of mosaic-free seed alone will not guarantee a mosaic-free crop, but the spread of mosaic may be delayed by the use of mosaic-free seed.

SELECTION OF EXPOSED FIELDS

The observation that the exposure of the bean field to certain meteorological conditions will largely govern the rate with which bean mosaic spreads was made in a survey of canning bean fields in New York State in 1932. Since that time experiments and observations have definitely established the point that mosaic spreads more slowly in bean fields situated on exposed knolls, slopes, and plateaus than in sheltered fields.

Thus it is possible to minimize the losses from bean mosaic by locating the bean field, if possible, on exposed slopes (especially western or southern slopes), on exposed knolls, or on exposed plateaus. Furthermore, bean fields should not be located too close to alfalfa or other legumes, especially on the lee side, since several times such fields have been observed to be more severely affected with mosaic than fields at some distance from legumes. Other factors may be involved, however, so that a negative correlation seems to exist.

FIELD ROGUING

The roguing of the infected plants as soon as they appear, a practice that has proved very successful in the control of virus diseases of potatoes, raspberries, etc., generally was not successful in the control of bean mosaic. The failure was due principally to the rapid rate with which the disease spreads under ordinary conditions in New York State. This point was well illustrated in one of the experimental fields at Geneva in 1932. The field was planted with an ordinary stock of Stringless Green Pod Refugee seed and rogued at weekly intervals. The field was first rogued when the plants were still in the simple leaf stage. At the fourth roguing, after 70 per cent of the plants had been removed, approximately 75 per cent of the remaining plants were infected with the disease; consequently, the experiment was discontinued. In cases like this, which were the rule in New York State in 1932, 1933, and 1934, roguing for the control of bean mosaic was not possible. In cases where the field was located on an exposed knoll, the disease was eliminated from the field by roguing because here mosaic did not spread very rapidly.

Roguing for the control of bean mosaic would have been successful in several sections of New York State in 1935 because mosaic spread very slowly, while in other sections of the State failure would have resulted because mosaic spread very rapidly.

Roguing for the control of bean mosaic, therefore, is a very uncertain practice and consequently cannot be recommended.

BREEDING AND SELECTION OF MOSAIC-RESISTANT STOCKS

The final and the logical way to control bean mosaic is to develop mosaic-resistant or mosaic-immune varieties of beans. If these mosaic-resistant or mosaic-immune varieties can be obtained by selection from a field in which the majority of the plants are affected then the problem is comparatively simple. If, however, the resistance or immunity to mosaic has to be obtained by breeding, then the problem is a long-time one and a complicated project. Unfortunately, the chances of accomplishing the former are very slim. Many healthy plants have been saved from fields in which practically all of the plants were infected, but their progeny always have proved to be susceptible to mosaic.

Since the forecast was made that all other attempts at controlling bean mosaic might fail, reciprocal crosses were made in 1932 between the mosaic-immune Robust pea bean and the Stringless Green Pod Refugee. The crosses were multiplied in the greenhouse during the fall and winter and tested under field conditions for immunity to mosaic in the summer of 1933. In the fall of 1933 one of the resulting mosaic-immune F_4 hybrids, which closely resembled a Refugee, was back-crossed on to the Stringless Green Pod Refugee so as to obtain more of the desirable characters of that parent and still retain the immunity of the Robust. These back-crosses have been multiplied in the greenhouse and tested for immunity under field conditions, as well as by inoculation experiments in the greenhouse, so that in some cases the seventh generation is under observation at the time of writing. Some of these back-cross hybrids possess many of the desirable characters for good canning varieties and are dark green in color. They are being watched with great interest. Commercial bean men who have seen these hybrids are greatly interested in them.

Further back-crosses were made in the fall of 1934 between certain of the original hybrids and the Stringless Green Pod Refugee. Crosses also were made between the back-cross hybrids and the Stringless Black Valentine and the Giant Stringless Green Pod. The F_3 generation of the majority of these hybrids was tested in the summer of 1935 and some were found to be worthy of further trials.

The Wisconsin Agricultural Experiment Station, in cooperation with the Idaho Agricultural Experiment Station, has introduced two

varieties, Wisconsin Refugee and Idaho Refugee, which are immune to bean mosaic, but whether or not they are suited to conditions in New York State has not been definitely established.

The problem of bean mosaic, in all probability, will be solved in the near future by the introduction of mosaic-immune or mosaic-resistant varieties.

SUMMARY

Bean mosaic, a serious disease of the popular canning variety Stringless Green Pod Refugee, is described in some detail. Under New York State conditions, it is confined almost exclusively to the bean. The mosaics commonly occurring on red clover, alsike clover, white sweet clover, alfalfa, peas, and black medick are caused by distinct viruses, altho some of them will infect the bean causing a disease known as yellow bean mosaic.

Results of the experiments on the effect of mosaic on the variety Stringless Green Pod Refugee show (1) that mosaic reduces the yield by 15 to 20 per cent and occasionally even more; (2) that mosaic causes the production of curved, misshapen, hydrotic, and frequently rough pimply pods; (3) that mosaic causes a delay in the blooming and podding periods, consequently more pickings may be necessary to get a smaller yield; (4) that the pods from mosaic-infected plants are darker in the can than the pods from healthy plants; and (5) that this darkened appearance is probably due to the hydrotic or water-soaked condition of the pods from the mosaic-infected plants.

Bean mosaic is a seed-borne disease. It is transmitted in the field chiefly by various sucking insects and to a slight extent by wind, cultivators, and other mechanical agencies.

The planting of mosaic-free seed and the roguing of the infected plants as soon as they appear occasionally were successful for the control of bean mosaic, but the results were too uncertain to warrant recommendation.

The introduction of mosaic-immune varieties will solve the problem of bean mosaic. These are being developed at this Station. It will be only a matter of time until they are ready for commercial production. Certain cultural practices, however, will aid in the reduction of bean mosaic. These are the selection of exposed knolls, plateaus, and hillsides and the isolation of the bean field from other legumes such as clovers and alfalfa.

